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Time of Perihelion Passage, 1849, Jan. 19, 39001, Berlin M.T.

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Motion Direct.

Substance of the Lecture delivered by the Astronomer Royal on the large Reflecting Telescopes of the Earl of Rosse and Mr. Lassell, at the last November Meeting.[*]

The Astronomer Royal gave that evening an account of the large reflecting telescopes of the Earl of Rosse and Mr. Lassell, which he had personally examined in the course of the last summer.

Premising that the subject might be considered interesting to the Society on these two grounds, first, that the reflecting telescope is exclusively a British instrument in its invention and improvement, and almost exclusively so in its use; and, secondly, that it had been almost exclusively the instrument of amateurs — a circumstance which seemed to prove both the difficulty of constructing it and its great excellence when properly constructed, — the Astronomer Royal remarked that his account would consist in some measure of a statement of the differences between the processes of these two amateur constructors. These differences, he thought, would be found well worthy the attention of all who were engaged in or contemplated the construction of reflecting telescopes. It is certain that both systems of methods are successful; and it may be doubtful how far the differences are connected with the difference of dimensions of the telescopes: for in all that follows it must be borne in mind that Lord Rosse's largest telescopes are 6 feet in clear aperture and more than 50 feet in focal length, while Mr. Lassell's are 2 feet in clear aperture and about 20 feet in focal length; that the thicknesses of the specula are nearly in the same proportion as their diameters; and hence that the weights of the specula are nearly as 27 to 1 (that of Lord Rosse's being about four tons, and that of Mr. Lassell's being about three hundredweight), a difference which in itself might be expected to require some difference of construction.

I. The first difference is in the constitution of the metal-mixture used for the speculum.

In Lord Rosse's specula the metal is purely a mixture of tin

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[*] The Astronomer Royal has been kind enough to furnish this account at the *urgent* request of the Editor, though with great inconvenience to himself. The polishing apparatus of Lord Rosse is described in his paper, *Phil. Trans.* 1840, p. 515, and figured in plate xxi. The polishing apparatus of Mr. Lassell is figured in his memoir, which is ordered for publication. Fellows can see models of both, and of Lord Rosse's gigantic reflector, at the apartments of the Society.

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and copper, in a proportion understood to be an atomic proportion, the weight of the copper being something more than double that of the tin. In the process itself there appears to be strong evidence that this proportion is truly atomic. When the metals are mixed in the intended proportions, it is found that the addition of one or two ounces of either metal to a mass of forty pounds of the mixture produces a difference so striking, that it is at once recognised by every person who is employed on the works. The mixed metal, when in fusion, possesses a remarkable union of penetrating power and of viscidity. It is so penetrating that Lord Rosse found it impossible to retain it in the ordinary cast-iron crucibles, which are cast with the mouth downwards; and he was compelled to have crucibles made expressly for this purpose, cast with the mouth upwards. It is at the same time so viscous, that when, in the casting of the speculum, the liquid metal is poured upon what Lord Rosse calls a "bed of hoops," that is, a broad base of the mould, formed by pressing together the flat surfaces of a great number of iron hoops, whose edges (trimmed into shape by turning and other mechanical operations) form the base, and through the interstices of which the air can escape; the metal itself does not in the smallest degree enter into these interstices. As soon as the cooling metal has acquired some consistency, it is dragged into the annealing furnace, every part of which has been brought to a low red heat. Great attention is given to the form of the floor of this furnace, as the metal is still in such a state that it receives figure from the furnace-floor. The furnace is then closed (care being taken to prevent one part from cooling, by radiation or convection, more rapidly than another), and after some weeks it is opened and the metal is taken out.

In Mr. Lassell's specula, the metal is made by first mixing copper and tin in the same proportions as those employed by Lord Rosse, and then adding a small quantity of white arsenic. It is well known that very great importance was attached to the admixture of arsenic by the principal constructors of reflecting telescopes in the last century. Lord Rosse has uniformly stated it as the result of his experience that, when the copper and tin are properly proportioned, nothing is gained by adding arsenic; Mr. Lassell is equally confident that the brightness of the metal is much improved by it. It would be idle to express an opinion on this point without comparing specimens of the two kinds of speculum-metal, side by side; and the Astronomer Royal only undertook to say that both bear a very high polish. The Astronomer Royal believed that the operation of annealing Mr. Lassell's mirrors was nearly similar to that for Lord Rosse's, although the trouble and risk of the process are of course materially diminished by the much smaller dimensions of the speculum.

The next step in Lord Rosse's operations is to turn (by a grinding process, with emery as the abrading powder) the edge of the mirror, the mirror being placed with its broad surface horizontal, with its lower surface and about one-third of its depth immersed in

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water, and being turned horizontally by a vertical spindle passing through a stuffing-box in the bottom of the water-vessel. The purpose of this turning is, to make a nearly air-tight fitting for a covering which is to be applied to the mirror when it is not in use, and with which is connected a box of quicklime, for the desiccation of the air in contact with the mirror; and the object of turning it in water is, to keep all parts of the speculum in the same temperature, a caution which is necessary in every part of the operations. This caution is probably requisite only for specula as large as those of Lord Rosse. For these it was found by Lord Rosse that if the iron grinder (to be mentioned presently) be washed with warm water, and be then applied to the speculum, the metal almost infallibly cracks. A surface of warm pitch may, however, be applied without producing the same bad effect.

II. The subject next worthy of attention, rather for the similarity of the methods of the two constructors than for their dissimilarity, is the method of mounting the mirrors. And this seems to be a proper place for mentioning the mounting, because it is indispensable (at least with Lord Rosse's specula) that the mirror be ground and polished on the very same supports, applied in the very same manner, as when the mirror is in use in the telescope.

The special object of Lord Rosse's support is this: supposing the surface of the speculum to be divided into any number of equal portions, each of a form not particularly elongated in any direction, then the supports are to be so arranged that every one of these portions shall necessarily sustain the same upward pressure, acting at its centre of gravity. At the same time it is necessary, for definiteness of support, that the ultimate support upon the fixed frame be upon three points. These objects are thus attained: the surface of the mirror is divided into twenty-seven equal portions, and these are grouped into nine groups, of three in each; to each portion is attached, by felt and pitch, a small plate of cast iron; and in a small hole sunk in this cast iron, opposite to the centre of gravity, a projecting pin of a triangular plane lever takes its bearing. This triangular plane lever is merely a triangle, having three points to sustain pressure, and a small hole for the fulcrum at the centre of gravity of the three points considered as equal weights; it is, then, evident that if that point is made really the fulcrum, the pressures at those three points are necessarily equal. The same construction being applied to each of the nine groups, then it is only necessary to support the nine fulcra in such a way that the pressures upon them are necessarily equal; and this is done by grouping three of their fulcra as points of pressure upon the three points of another and stronger triangle, whose fulcrum is at the centre of gravity of these three points considered as equal weights; and this fulcrum is one of the points of the fixed frame. It will thus be evident that every one of the first-mentioned pins sustains exactly one twenty-seventh part of the whole weight of the mirror, or rather of the whole pressure of the mirror perpendicular to its surface, neither less nor more. (When the mirror is in the telescope,

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it exerts also an edgewise pressure, which in Lord Rosse's construction was at first sustained by fixed pillars of the fixed frame; of these more will be said hereafter.) The fixed frame has small wheels; while it is in the grinding trough, it is so lifted off the wheels that it takes a firm bearing upon the rotating-frame; when it is to be carried to the telescope it is lowered to take bearing upon its wheels, the side of the grinding-trough is taken off, the fixed frame carrying the speculum is wheeled upon a proper carriage, the carriage conveys it to a place very near the telescope, where is a railway at proper height for receiving the small wheels; the telescope is placed vertical, its lower end is opened, and continuation-rails are laid to it, and the fixed frame is thus wheeled into the telescope, carrying the mirror; then by powerful screws the bearing of the fixed frame is received upon three points, the wheels being entirely lifted off their bearings. (Since giving this account, the Astronomer Royal has learnt from Lord Rosse that a speculum which was raised for a few minutes only from its lever-bearings received in that time a permanent change of figure.)

In Mr. Lassell's operations the speculum is supported on eighteen points, the grouping being first made by two and two, with straight levers, and then the fulcra of the straight levers being by means of triangular levers supported upon three ultimate points. The Astronomer Royal was not able to say whether the same cautions, as to retaining the speculum at all times upon the same bearings, which Lord Rosse found necessary, were required for Mr. Lassell's mirrors; but it is evident that the difficulties of support of every kind are here very much less. The edgewise pressure, when in the telescope, is here supported by a semicircular iron hoop, of which more will be said hereafter.

III. The next point deserving special comparison is the apparatus for grinding and polishing.

The apparatus used by Lord Rosse imitates very closely, but with that superior degree of regularity which is given by machinery, the operation of polishing by hand. Proceeding from the quick motions to the slow ones, the order of movements is as follows:—(1.) By a steam-engine, a rotatory motion round a vertical spindle is given to a crank, which by a connecting rod acts upon a sliding rod that moves the grinder or polisher backwards and forwards. This sliding rod passes through a fixed guide at the end next the connecting rod, and through a slowly moving guide [described under (2)], at the other end; and thus every stroke of the grinder is very nearly a straight stroke. The sliding rod is interrupted in its middle, and there its place is supplied by a hoop which loosely surrounds the grinder: this construction is necessary, because, on account of the great size and weight of the grinder, it is necessary that it be supported by counterpoises in various parts, at the same time that it is necessary that (in order to prevent the formation of striæ in a definite direction on the grinder) the grinder be left free to revolve: that motion of revolution is given merely by the friction

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upon the mirror, whose rotation will be mentioned under (3), and depends upon the weight with which the grinder presses the mirror. (2.) A band from the crank-spindle (1) passes round a wheel which carries a crank, in which is the forked guide (turning by a spindle in the crank end), that guides the distant end of the sliding rod; and thus the strokes of the grinder do not pass uniformly over the centre of the mirror, but pass in their direction a certain distance to the right and left. But as, in the ordinary crank motion, the duration of the strokes at the extreme right and left would be too great, the wheel on the spindle of this grinding-crank is elliptical, the proportion of its axes being about three to one: its angular motion is, therefore, unequal; and the strokes are thus made to dwell a shorter time near the extreme right and left, and a longer time near the centre. (3.) Another band from the crank-spindle (1) passes round a large wheel on the vertical axis, that passes through a stuffing-box in the bottom of the grinding-trough, and there carries a broad frame, on which is placed the fixed frame of the mirror, supporting the mirror itself. Thus the mirror turns slowly round to receive the strokes of the grinder in every direction. It is only necessary to add to this, that a large part of the grinder's weight is equally supported at twelve points, by a lever counterpoise above it, which supports the centre of a triangle, each point of which (by a roller over which a cord passes) supports two points, each of which points is the middle of a straight lever whose ends are attached to the grinder.

In Mr. Lassell's apparatus (omitting some details, which are not now necessary, as a detailed account of this apparatus has lately been given by Mr. Lassell himself to the Society), the steam-engine puts in motion (1) a vertical spindle below, which turns the mirror slowly, and (2) a vertical spindle above, which has a horizontal arm, in which is a planet-wheel turned by its tooth-connexion with a fixed sun-wheel. The axis of this planet-wheel carries another wheel that works in a third wheel, whose spindle is carried by the horizontal arm, but whose place can be fixed at pleasure near to or far from the centre of the vertical spindle (2). An arm from the spindle of the third wheel carries a spike pointing downwards (the distance of this spike from the centre of the spindle of the third wheel being adjustable), and this spike lodges loosely in the centre of the grinder and moves it upon the face of the mirror. Thus it will be seen that the centre of the grinder is always moved in an epitrochoid (including the circle as a possible case, if the adjustment is made for that curve), in which the proportion of velocities of the two circles is fixed, but the radii and their proportions are adjustable. The grinder, as in Lord Rosse's construction, is allowed to take freely the rotatory motion which it may receive from the friction on the mirror; but no counterpoise is used, the weight of the grinder being comparatively small.

The essential difference of these constructions, as regards the movements of the grinder, is, therefore, this: that in Lord Rosse's

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apparatus every stroke is very nearly straight, while in Mr. Lassell's apparatus there is no resemblance to a straight movement at any part of the stroke.

IV. The process of grinding is nearly the same (with differences corresponding to the difference of dimensions) in the operations of both constructors.

In Lord Rosse's grinding, the speculum having received an approximate figure from the form of the annealing furnace, the cast-iron grinder is brought very exactly to form by turning upon the lathe, with proper reference to a gauge, and (if not done before) its surface is scored with cross-furrows about two inches apart and nearly an inch deep, leaving the acting part of the surface in squares. The grinder is then mounted in the apparatus; and this is the most dangerous part of the whole operation. The slightest jar of the iron grinder upon the mirror would break the mirror; and to avoid this risk, a great number of thin wooden wedges is placed upon the edge of the mirror, the grinder is slowly lowered upon them, and then by degrees they are gently withdrawn. The grinder is then used to grind the surface, with the intermediate powder of emery and water; coarser and finer emery in succession. A heavy weight is allowed to press the grinder upon the mirror; and as the grinder itself suffers much in form, it is repeatedly re-turned upon the lathe. This operation sometimes lasts many days.

Of the grinder used by Mr. Lassell, the Astronomer Royal could give no account, but believes that it is of wood, the same which is used for polishing. The abrading powder used is the same as Lord Rosse's (emery, coarser and finer in succession).

V. The next point deserving attention is the important process of polishing.

When the figure of the speculum given by grinding is supposed by Lord Rosse to be sufficiently accurate, the projecting squares of the cast-iron grinder are covered with a coating of resin and turpentine, of such a consistence that, at a temperature of about 50° Fahrenheit, the nail can easily make an indentation in it. This is then covered with another coating, of a substance formed by combining the mixture last-mentioned with a certain quantity of wheat-flour, and of such a consistence that, at a temperature of 80° Fahrenheit, the nail can make an indentation in it. It is not to be understood that there is any particular virtue in the temperatures 50° and 80°, but (for reasons to be hereafter given) it is necessary to have two strata of different degrees of hardness (the harder being the exterior), and the hardnesses defined by those two temperatures having been used in many experiments, the other adjustments have been determined, using these as bases; and if these bases were now changed, every other adjustment must be changed.

The necessity for the different strata of resin is thus explained. It is necessary that the polisher yield a little, else the polishing surface could not be in contact with the mirror at all parts of its stroke (the mirror being supposed parabolical), and this yielding is given by the first or soft stratum. But it is also necessary that the

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stratum next to the metal be hard; for if, in passing across a scratch or furrow, it were able to accommodate its form to that of the furrow, it would round off and polish the edges of the furrow, and this would very much injure the image of a bright object.

The coating is heated to softness by the flame of a torch, and the grinder is then lowered upon the mirror, and the coating takes the proper form. The mirror is exposed to no danger of cracking from this application.

The powder used is the red oxide of iron, prepared by precipitating (by means of ammonia) the black oxide of iron from a solution of sulphate of iron, and then heating the black oxide in a furnace with access of air. Lord Rosse finds that no other method of preparing the red oxide is successful. No polishing-putty or other powder of any kind is employed.

The powder is moistened with water to a degree known by experience, and then, the counterpoise of the grinder being so much increased that the remaining friction is enough to turn the grinder only once for about sixteen revolutions of the mirror, the operation goes on for about eight hours. It is essential, for reasons similar to those lately mentioned, that the temperature of the air and the temperature of the dewpoint have nearly certain definite values (the latter, that the water mixed with the powder may dry in the proper degree): if the external air is too dry, the air of the room is moistened by a jet of steam; if it is too damp, the polishing is not attempted.

After about eight hours, the grinder is lifted and a fresh application is made of powder mixed with "ammonia soap," a substance formed by treating common soap with ammonia. The metal then dries more rapidly, and the labour to the engine becomes much greater: the work is continued till the surface is dry, or very nearly dry; the grinder is taken off, and the mirror is found finished, having a parabolic figure, and a very high polish.

It is to be remarked here that the smaller mirrors made by Lord Rosse (3 feet diameter, about 25 feet focal length) were tried before they were used, by means of an object fixed something more than 50 feet above them, whose image accordingly is found at something less than 50 feet above them. But for the larger mirror, such a trial is impracticable (the height of the object must exceed 100 feet), and the mirrors have, therefore, been placed in the telescope without any trial, and their definition has been found perfect.

Mr. Lassell uses for polisher a wooden plate formed of two thicknesses of pine-wood with the grain crossed; and this apparently yields to accommodate itself to the form of the mirror. In the arrangement of its square protuberances, it is similar to Lord Rosse's; but it is covered with only one coating of pitch. The polishing powder used is the same as Lord Rosse's. The Astronomer Royal believed that the attentions to temperature, moisture, &c., which Lord Rosse found indispensable for his large mirrors, are not found necessary by Mr. Lassell. Mr. Lassell finishes the operation with the speculum wet.

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VI. The next point to which allusion was made is the form and mounting of the telescopes.

Lord Rosse's telescope is a wooden tube, its interior diameter exceeding 6 feet in every part, being at the middle about 7 feet, and nearly 50 feet in length. This is fixed to a cube of 10 feet, which has folding-doors on that side which, when the telescope is horizontal, is the upper side (at which side the fixed frame supporting the mirror is introduced, as has already been said), and which carries the fixed frame by three large screws in that side of the cube which is opposite the mouth of the telescope. To this side of the cube is attached the universal joint by which the lower end of the telescope is connected with a fixed support, the joint being a few feet below the general surface of the ground. On each side (east and west) of the telescope is an enormous pier of solid masonry, about 70 feet long, in the north and south direction, between 40 and 50 feet high, and in its thickest part nearly 20 feet thick. (None of these dimensions are taken from actual measure.) The fixed support is nearer to the north than to the south ends of these piers. Near the top of the piers, on the interior faces, in the east and west plane passing through the universal joint, are two cranes with pulleys (the turning crane being no bigger than suffices to carry a large pulley, whose edge is in the vertical axis of the crane); over these cranes the chains pass which are attached to the telescope; and to the lower ends of the chains, after they have passed fixed pulleys on the walls, are attached the counterpoises, weighing about four tons each. These counterpoises are not allowed to depend freely, but are connected by bridle-chains with wooden horns that project from the north ends of the piers; the effect of this arrangement is that when the telescope tube is nearly horizontal and the force required to support it is very great, the weight of the counterpoises acts very nearly vertically on the chains, and is entirely effective for the support of the telescope; but when the telescope is considerably elevated and less supporting force is required, the weight of the counterpoises is supported in a great measure by the bridle-chains, and very little tension is given to the supporting chains. For the sake of supplying some slight defects in the laws of tension thus produced, and also for the sake of constantly producing a small tendency in the telescope towards the south horizon, other counterpoises, in a pit south of the fixed support, are brought successively into action as the telescope is raised. There is then only a comparatively small and very manageable tendency of the telescope towards the south, and this is supported by a light chain which passes over a pulley on a bar connecting the horns before mentioned (the pulley being in the direction of a polar axis passing through the lower universal joint, and the motion of the telescope, therefore, for a given length of the chain, being equatoreal), and this chain is shortened or lengthened, and the telescope is thereby raised or depressed, by a windlass a little way north of the fixed support. Upon the inner face of the eastern pier is an iron arc of a circle, upon which slides a runner

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connected with a rod that passes through a frame on the telescope-tube and near to its mouth, and is there racked for working with a pinion: by the movement of this pinion the distance of the telescope from the pier is altered, and thus a motion in hour-angle is given. At the south ends of the piers there are strong ladders, upon which (assisted by counterpoises) there slides a stage; upon which stage a small observing box travels east and west: this is used for observing, so long as the mouth of the telescope is below the end of the pier. For greater elevations, the top of the western pier being shaped by slopes so as to approximate to a circular arc, there are mounted upon it curved galleries, which are carried by beams that run above and below pulleys fixed to the top of the pier; and the galleries are carried out by rack-and-pinion work, to approach the side of the telescope. It is intended to give the power of observing as far north as the pole; but at present the galleries extend only to the zenith. The telescope is Newtonian, the minor axis of the small mirror being about six inches, and the observer looks into the side of the tube.

Mr. Lassell's tube is of sheet iron, and this tube is not carried immediately by the mounting, but is inserted in a long box of cast iron, in which it can be turned round its own axis. This movement is necessary to place the eyepiece exactly in the same side-position in all directions of the telescope, and also to cause the edgewise support of the mirror to act always in the same way. The long box is mounted equatoreally, the polar axis turning in two bearings below the declination axis, and carrying an hour-circle, upon which are fixed two supports, in which turn the two pivots of the declination axis of the long box. The telescope is Newtonian, the eyetube being in one side; but the smaller dimensions of the small mirror (a diameter of 2 inches only being required) enable Mr. Lassell to use the reflection at the internal surface of a glass prism, by which much more light is reflected than by a metallic reflector. At first much annoyance was caused by the deposition of dew on the glass, but this was remedied by attaching to it a case carrying a small piece of heated lead; and, when proper attention is given to the inclosure of the lead, no inconvenience is sustained from the effect of the hot metal in disturbing the air in the tube of the telescope. The whole is covered by a revolving dome 30 feet in diameter, and the observer is mounted for observation on a stage which is carried by the dome.

The Astronomer Royal then proceeded to describe some of the difficulties to which instruments of this class are yet liable, founded partly upon his own observations with Lord Rosse's telescope.

Upon directing the telescope to an object very near the zenith, it was seen very well defined; or, at least, with no discoverable fault. It must be remarked that the image of a star never assumes the neat spherical form to which the eye of an observer with a fine refractor is so much accustomed. This arises evidently from the circumstance that (from the great aperture of the mirror) the diffraction image and diffraction rings are invisibly small, and the

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form of the blurred image is probably determined by the irregular sensibility of the nervous membranes of the eye. The same effect exactly is produced by a large refractor when a power is employed too low to exhibit the rings.

But when the telescope was directed to a star as low as the equator its image was very defective. The defect, however, followed that simple law which the present Master of Trinity College has described by the word *astigmatism*. When the eyepiece was thrust in, the image of the star was a well-defined straight line, 20 seconds long, in a certain direction; when the eyepiece was drawn out a certain distance (about half an inch from the former position) the image of the star was a well-defined straight line, 20 seconds long, in a direction at right-angles to the former. Between these two positions the image was elliptical, or, at the middle position, a circle of 10 seconds diameter. The image of *Saturn* (then without a ring) was, in the two positions above mentioned, an oval (not an ellipse), whose length was about double its breadth; or, in the middle position, it was a confused circle, whose diameter was about 30 seconds instead of 20. The position of the astigmatic lines had no distinct relation to the vertical plane; and this circumstance, as well as the magnitude of the astigmatism, proved that it was not produced by a tilt of the mirror.

Lord Rosse immediately suggested a probable cause of this defect. The triangular levers which support the mirror are all, to a certain degree, elastic. When the telescope is dropped from the vertical position, the edge of the mirror begins to press the fixed pillars in the fixed frame mentioned under No. II.; and as the edgewise pressure increases faster than the excess of the elastic force of the levers over the pressure on the levers, the edge is firmly locked to the pillars by the friction against them. When the telescope is much depressed this friction is perhaps not much less than two tons, or is equal to the greatest strain of six horses, all exerting a force perpendicular to the face of the mirror at a part intended to sustain no such force, and therefore tending to bend the mirror out of shape. The obvious remedy was to suspend the edge of the mirror in such a manner as to leave it free to play in a direction perpendicular to the face of the mirror; and for this purpose, first an iron hoop, and secondly a chain, were used, the bearing against the pillars being entirely destroyed. The effect was at first very satisfactory; definition was made very good; *Saturn's* ring was well seen on September 2 as a narrow line. But in subsequent observations the effect was not so satisfactory. Here, again, Lord Rosse discovered the cause. The triangular levers which immediately support the mirror are necessarily not plane, inasmuch as the points which take hold of the plates that adhere to the mirror must project higher (the telescope being vertical) than the fulcra of these levers. If, then, when the telescope is lowered, the mirror is allowed to slip edgewise, it throws the lower points of each lever partly out of bearing, and then the mirror is not supported

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in the way to which its figure is adapted. It was found that some of the points were not in bearing; and it was also found that, when the telescope was directed to a star, the image was rendered extremely good by screwing or unscrewing to the proper degree the supports of the hoop or chain. It was found, moreover, that all this adjustment was affected by the bending of the iron base of the fixed frame. On the whole, this part of the mounting is not in a satisfactory state. The Astronomer Royal was not able to say what is the nature of the edge-bearing adopted by Lord Rosse at the present time; still it is evident that, with due attention, the mounting above-mentioned may be made perfectly available. [The Astronomer Royal has lately been informed, that Lord Rosse has entirely overcome these difficulties, by placing, between the back of the mirror and the plates in which the points of the triangular levers act, sheets of tin, which allow the mirror to slip upon the plates, instead of the felt and pitch, which formerly united the mirror and the plates.] It may be proper here to mention, that Lord Rosse has informed the Astronomer Royal, that the mirror which he saw under the polisher has been mounted, and that it shews very well the third star of γ *Andromedæ*,—no small proof both of the perfection of the figure and of the efficiency of the support of the mirror in that position.

The Astronomer Royal then explained his own ideas upon the nature of the mounting, to which (whatever might be the practical difficulties in the mere mechanical operation) he thought it would be necessary to approach. He thought that it was absolutely necessary to give the edge-support by counterpoises; and this might be done, retaining the present levers, by making the point of each of the small triangles a socket for a ball-and-socket joint, in which turns a lever whose point lodges in the mirror. The extreme hardness of the speculum metal makes it, however, difficult to drill the holes.

In terminating now the account of the mirror, the Astronomer Royal alluded to the impression made by the enormous light of the telescope; partly by the modifications produced in the appearances of nebulæ figured by Sir John Herschel, partly by the great number of stars seen even at a distance from the Milky Way, and partly from the prodigious brilliancy of *Saturn* (the only planet which he had an opportunity of seeing). The account given by another astronomer of the appearance of *Jupiter* was, that it resembled a coach-lamp in the telescope; and this well expresses the blaze of light which is seen in this instrument.

The Astronomer Royal then stated that he had had no opportunity of trying Mr. Lassell's telescope; but he had understood from Mr. Lassell that some difficulties had been found in the arrangement of the edge-bearing of the mirror, which had been overcome by suspending it in an iron hoop. These, however, from the great difference of dimensions, would probably be trifling compared with those of Lord Rosse's mirrors.

Adverting again to the mounting of these telescopes, the Astro-

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nomer Royal suggested for consideration whether it might not be advantageous to mount the telescope with an altitude and azimuth movement, by an overhanging fork inserted in a vertical pillar. If a rod were joined to the stalk of this fork, and, by means of an ordinary parallel motion, were compelled to move parallel to the axis of the telescope, and if any part of this rod were connected by another rod (adjustable in length according to the polar distance of the object) to a universal joint on the ground, in such a position that the line drawn from that universal joint to the stalk of the fork is a polar axis, then the motion of the telescope would be equatoreal. For the observer, it was proposed that an observing-box should be fixed to the telescope, and that the access should be by a spiral staircase round the pillar, by a narrow platform near its top, and by a staircase along the side of the tube.

In conclusion, the Astronomer Royal observed that it was impossible to overrate the advance that had been made in the construction of telescopes by the two amateur constructors of whom he had spoken. Lord Rosse had shewn that it was possible, without any important manual labour, to produce with certainty, by means of machinery, mirrors of a size never before attained, and perhaps with a perfectness of definition which had not been reached before; and he had, by publication and by private communication, made these methods accessible to the world. This success was the more remarkable, because the whole of the work was done by workmen found on the spot; even the steam-engine, by which (to a late time) the whole of the machinery was driven, was made by native workmen under Lord Rosse's personal instructions. To Mr. Lassell also much was due, for the example which he had set of what may be done by a man possessing less ample means, and whose time is fully occupied in business; and much also for the elegant and compendious and manageable apparatus arranged by him, which promises to be of the greatest use in the construction of large object-glasses as well as of mirrors.

On Irradiation. By Professor Powell.

After adverting to the history of researches on this subject, the author dwells particularly on the method of exhibiting the phenomenon adopted by M. Plateau, which forms the basis of all his own experiments, and which consists of a card or lamina, cut so that one half of a long parallelogram is cut out whilst the other remains, having the portions at the sides cut away. Viewed against the light, the enlargement of the bright half, in breadth, is seen contrasted with the opaque, and might be subjected to measurement.

The first question on the subject refers to the supposition of a peculiar *physiological cause* affecting the eye to produce the apparent enlargement of the bright image. After fully allowing for some portion of such phenomena being fairly attributable to ocular